# LASERS IN MARITIME ENVIRONMENT

## OBJECTIVE: STUDY LASER LIGHT PROPAGATION AND SCATTERING UNDERWATER

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# RESEARCH MOTIVATION AND EXPERTISE

- SOME OF THE CURRENT OBJECTIVES OF LASERS  PROPAGATION AND SCATTERING UNDERWATER IS LARGE DATA VOLUME LINKS IN THE LINE-OF-SIGHT AND HIGH RESOLUTION CLOSE DISTANCE IMAGERY
- **NAVY LASER MINE DETECTION NOW OPERATIONAL** Published 28 march 2017

  The Airborne laser mine detection system uses pulsed laser light and streak tube receivers housed in an external equipment pod to image the entire near-surface volume potentially containing mines. *It emits pulsed blue-green laser wavelength of about 510nm, which allows it to operate in a depth of up to 200 meters. As stated in publications from the geoscience and remote sensing symposium, the system subtracts the time between the reflections of the laser beams that bounce off of the water's surface and the reflections of laser beams that penetrate the surface in order to calculate depth and orientation.*
- THE CHALLENGE OF LASER LIGHT PROPAGATION AND SCATTERING UNDERWATER IS DOMINATED BY THE ATTENUATION OF THE LIGHT INTENSITY AND THE COMPLEXITY OF THE MARITIME ENVIRONMENT.
- WE BRING IN THE EXPERTISE IN CREATING LASER LIGHT WITH VARIABLE DEGREE OF COHERENCE AND POLARIZATION, AND MEASURING THE LIGHT INTENSITY FLUCTUATIONS PERFORMANCE IN THE FIELD
  - ✓ THESE LASER BEAMS EXPERIENCE LOWER LEVELS OF SCINITALTION IN ATMOSPHERIC OPTICAL TURBULENCE
  - ✓ THEORETICAL STUDIES SUGGEST IMPROVED PERFORMANCE IN OTHER COMPLEX MEDIA
- UNDERWATER TEST BED UNDER CONSTRUCTION
  - ✓ LARGE 6 FT WATER TANK ACQUIRED
  - ✓ TEMPERATURE ACTUATORS AND SENSORS INITIAL CALIBRATION PERFORMED
  - ✓ WATER FLOW ACTUATION AND SENSING TESTED,
  - ✓ STUDENT LED EFFORT WITH A GOAL OF PROVIDING A CONTROLLED TEMPERATURE AND FLOW IN MARITIME ENVIRONMENT FOR UNDERWATER LASER TESTING

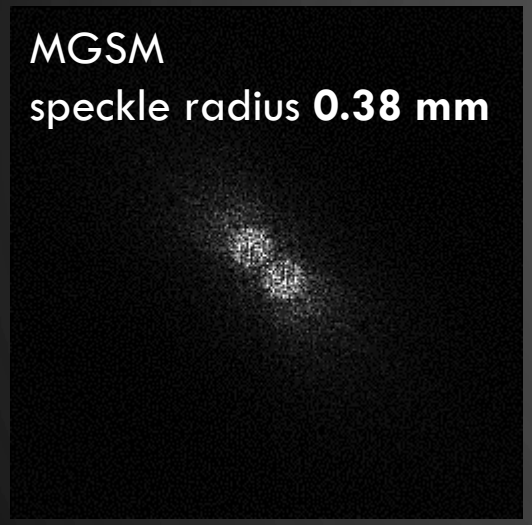
# EXPERIMENTS

- ✓ GENERATE SPATIALLY PARTIALLY COHERENT FLAT TOP BEAMS WITH VARYING DEGREES OF COHERENCE, EXPRESSED AS SPECKLE SIZE
- ✓ CONSTRUCT SINGLE POLARIZATION BEAMS AND COMBINED BEAMS, BOTH VERTICALLY AND HORIZONTALLY POLARIZED BEAMS PROPAGATED SIMULTANEOUSLY.
- ✓ ISOLATE BEAM MODE TO BE EXPERIMENTALLY USEFUL
- ✓ PROPAGATE THE BEAM FOR AT LEST 20 FT IN ORDER TO DEVELOP PATTERN FROM SPATIALLY DISTRIBUTED BEAMLETS
- ✓ PROPAGATE THE BEAM THRU A WATER TANK WITH SPECIFIES SALINITY
- ✓ ENGAGE A MECHANICAL AGITATOR TO MOVE SCATTERERS IN THE WATER (VARIOUS RANDOM DUST PARTICLES), ACHIEVE STATIONARY SCENARIO
- ✓ PROVIDE STILL CONDITIONS IN WATER FOR COMPARISON CASE
- ✓ SET UP A CAMERA IN THE BEAM'S DIRECT PATH TO RECORD THE PROPERTIES OF THE LASER LIGHT INTENSITY FLUCTUATIONS
- ✓ SET UP A CAMERA TO OBSERVE FORWARD PATH SCATTERING
- ✓ COLLECT MEASUREMENTS FOR ARRAY OF CONDITIONS
- ✓ PROCESS THE DATA FINDING MEAN INTENSITY, SCINTILLATION INDEX AND PROBABILITY DENSITY FUNCTION
- ✓ REPEAT FOR THE VORTEX BEAMS

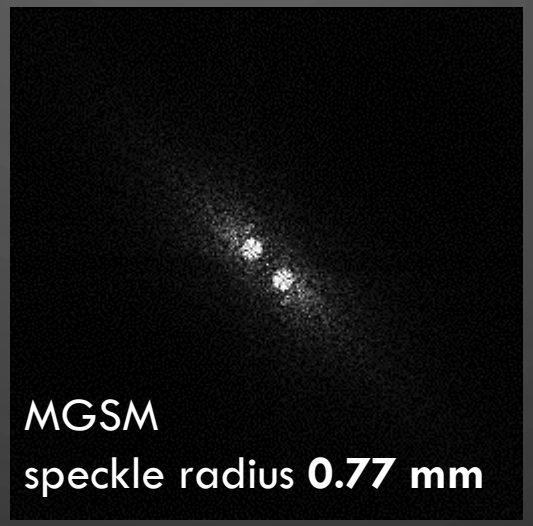
# EXPERIMENTAL SET UP

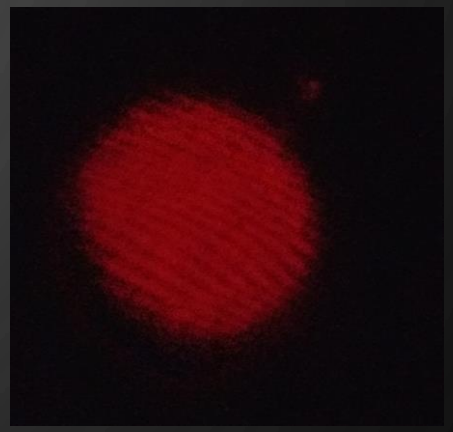
- Laser light, vertically polarized, from the source is expanded to best utilize SLM
- SLM generates screens to create specific light pattern (MGSM)
- After the screen is generated vertical polarization is confirmed optically
- Laser beam is split
- One lag is reflected from the mirror (this is vertically polarized component)
- Along the other lag the polarization of the light is changed using half plate
- This horizontally polarized light is reflected from a mirror
- Both vertically and horizontally polarized light is combined
- Iris is used to select appropriate beam mode for propagation
- Beam is propagated for 30 feet before going through a water tank 3 feet long
- Laser light propagation and scattering
- is captured using 2 cameras

# MULTI GAUSSIAN SCHELL MODEL BEAM GENERATION

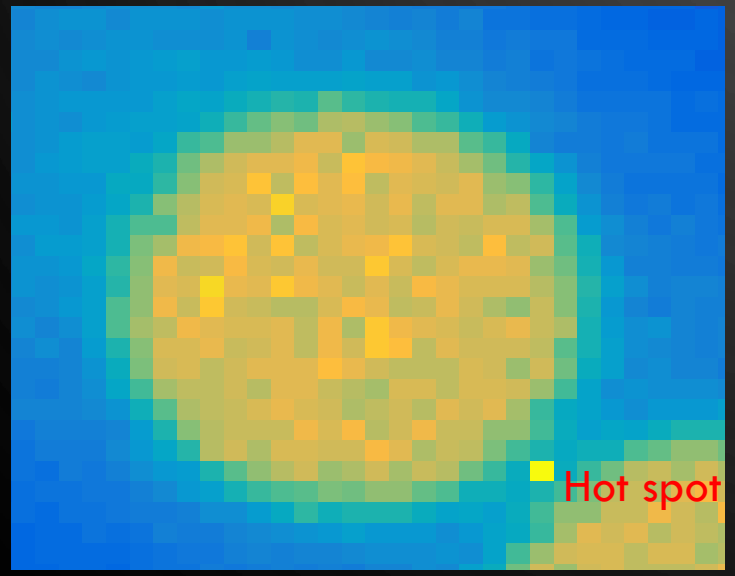


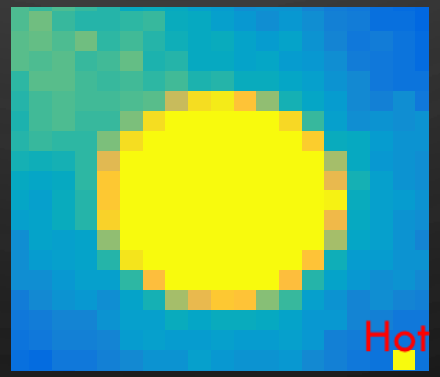

Generated beams using SLM,
note the hot spot and
shifted modes due to the use of a grid



Experimentally
generated
MGSM Beam

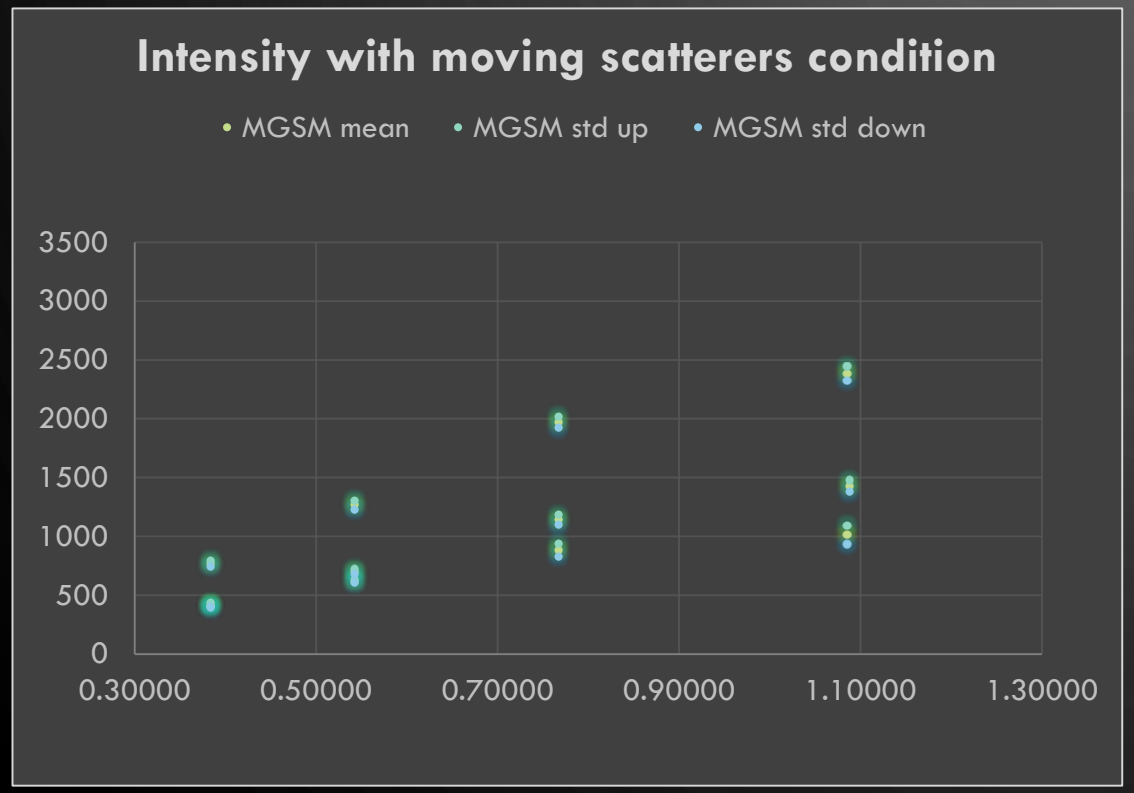


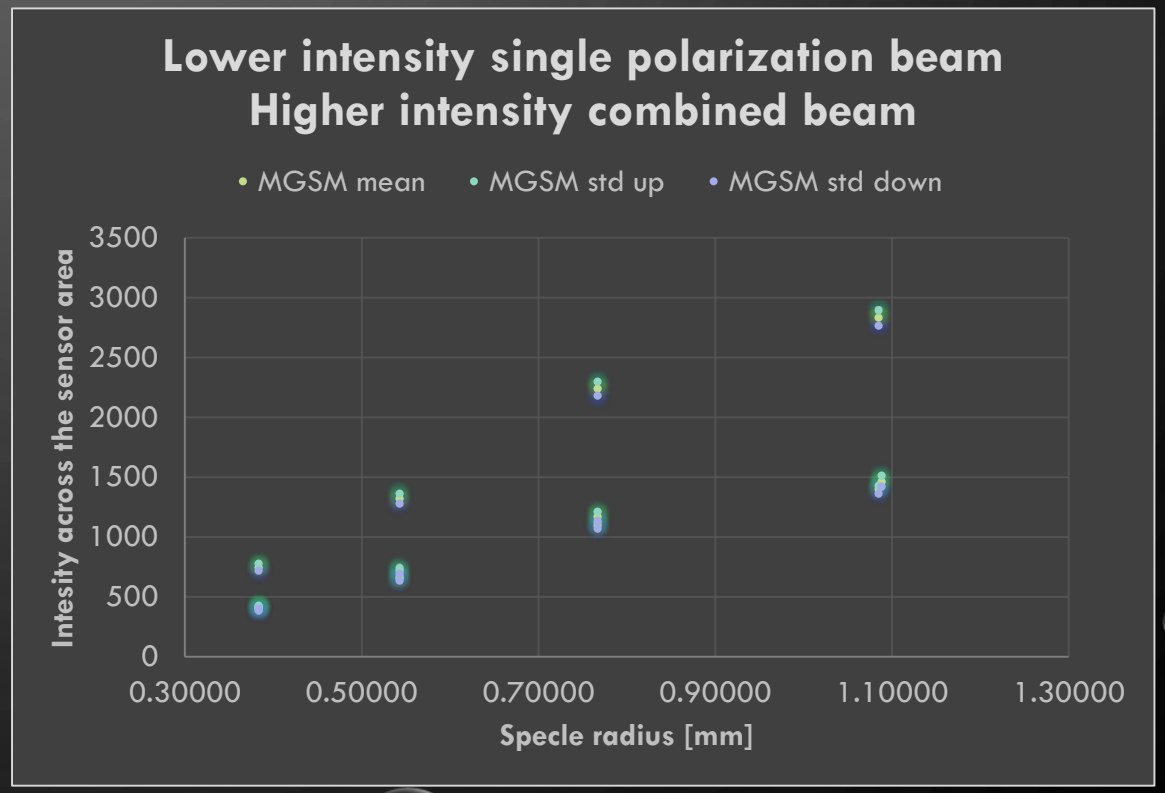




Simulation from SLM screen, cropped to reflect use of iris

# MEAN INTENSITY

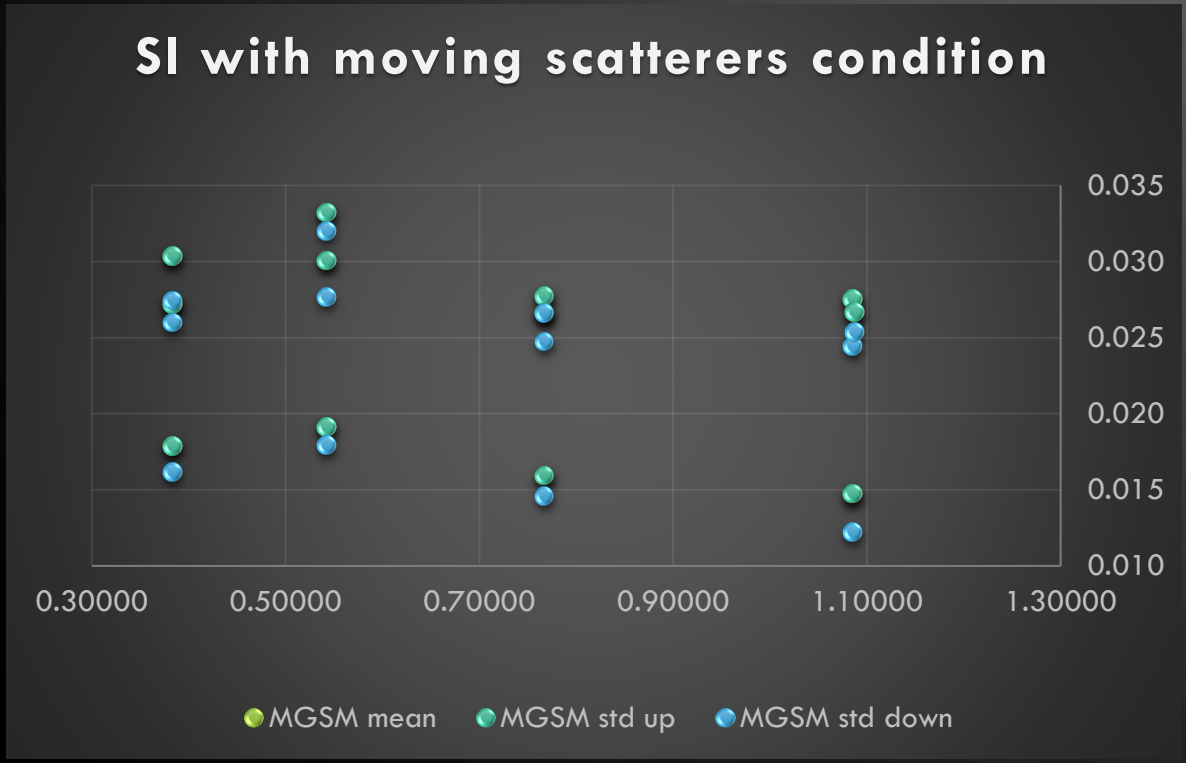
## FOR THE VARIOUS SPECKLE SIZES WHEN THE FLAT TOP LASER BEAM IS PROPAGATED TROUGH A WATER TANK IN STILL CONDITIONS AND WITH THE MOVING SCATTERERS

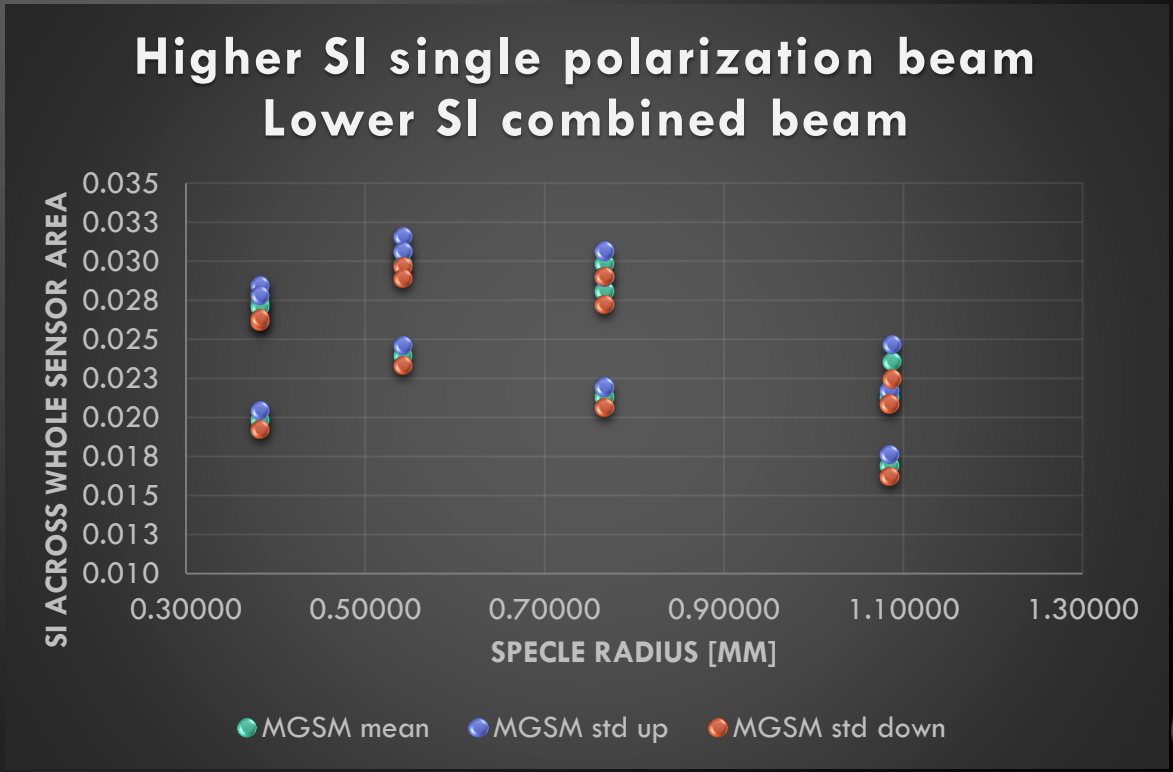


# SCINTILLATION INDEX

## FOR THE VARIOUS SPECKLE SIZES WHEN THE FLAT TOP LASER BEAM IS PROPAGATED TROUGH A WATER TANK IN STILL CONDITIONS AND WITH THE MOVING SCATTERERS



# SUMMER PLANS

## SCHEDULING

## 22 WORKING DAYS

- ✓ ONR FUNDING FROM 14 JUNE TO 14 JULY
- ✓ COLLABORATION WITH ABBIE WATNIK FROM NRL ON LASERS UNDERWATER, INITIAL VISIT JUNE 13
- ✓ OSA CONFERENCE 25 JUNE 1 JULY
- ✓ FROM 14 TO 23 JUNE PREPARING THE MATERIAL FOR THE CONFERENCE
- ✓ FROM 2 TO 14 JULY WRITING A JOURNAL PAPER

## OBJECTIVE

## LASER UNDERWATER EXPERIMENTS:

## MITIGATING THE EFFECTS OF MARITIME ENVIRONMENT ON LASER BEAMS

- RUN THE EXPERIEMNTS TO ESTABLISH PROPAGATION AND SCATTERING DEPENDANCE OF
  - BEAM INTENSITY,
  - SCINTILLATION AND
  - PROBABILITY DENSITY FUNCTION
- ON LASER BEAMS WITH
  - VARIABLE COHERENCE LEVEL AND
  - POLARIZATION
- GOALS
  - VERIFY THE BENEFIT OF SIMULTANEOUS PROPAGATION OF DIFFERENTLY POLARIZED LASER BEAMS IN COMPLEX ENVIRONMENT
  - ESTABLISH COHERENCE LEVEL ‘SWEET SPOT’ IN VARIOUS MARITIME CONDITIONS

## Publication list from Google Scholar

1. Flatness parameter influence on scintillation reduction for multi-Gaussian Schell-model beams propagating in turbulent air S Avramov-Zamurovic, C Nelson, S Guth, O Korotkova Applied optics 55 (13), 3442-3446 2016
2. Scintillation reduction in pseudo Multi-Gaussian Schell Model beams in the maritime environment C Nelson, S Avramov-Zamurovic, O Korotkova, S Guth, R Malek-Madani Optics Communications 364, 145-149 2016
3. Experimental study of electromagnetic Bessel-Gaussian Schell Model beams propagating in a turbulent channel S Avramov-Zamurovic, C Nelson, S Guth, O Korotkova, R Malek-Madani Optics Communications 359, 207-215 2016
4. Scintillation reduction in multi-Gaussian Schell-model beams propagating in atmospheric turbulence O Korotkova, S Avramov-Zamurovic, C Nelson, R Malek-Madani, Y Gu, ... SPIE Optical Engineering+ Applications, 92240M-92240M-7 2014
5. Polarization-induced reduction in scintillation of optical beams propagating in simulated turbulent atmospheric channels S Avramov-Zamurovic, C Nelson, R Malek-Madani, O Korotkova Waves in Random and Complex Media 24 (4), 452-462 2014
6. Probability density function estimation of laser light scintillation via Bayesian mixtures EX Wang, S Avramov-Zamurovic, RJ Watkins, C Nelson, R Malek-Madani JOSA A 31 (3), 580-590 2014
7. The dependence of the intensity PDF of a random beam propagating in the maritime atmosphere on source coherence S Avramov-Zamurovic, C Nelson, R Malek-Madani, O Korotkova Waves in Random and Complex Media 24 (1), 69-82 2014
8. Probability density functions of power-in-bucket and power-in-fiber for an infrared laser beam propagating in the maritime environment C Nelson, S Avramov-Zamurovic, O Korotkova, R Malek-Madani, R Sova, ... Applied optics 52 (31), 7449-7461 2013
9. Measurements of partially spatially coherent laser beam intensity fluctuations propagating through a hot-air turbulence emulator and comparison with both terrestrial and maritime environments C Nelson, S Avramov-Zamurovic, O Korotkova, R Malek-Madani, R Sova, ... SPIE LASE, 86100T-86100T-12 2013
10. Measurements and comparison of the probability density and covariance functions of laser beam intensity fluctuations in a hot-air turbulence emulator with the maritime atmospheric environment C Nelson, S Avramov-Zamurovic, R Malek-Madani, O Korotkova, R Sova, ... SPIE Optical Engineering+ Applications, 851707-851707-12 2012
11. Probability density function of partially coherent beams propagating in the atmospheric turbulence O Korotkova, S Avramov-Zamurovic, C Nelson, R Malek-Madani SPIE LASE, 82380J-82380J-12 2012
12. Probability Density Function (PDF) of intensity of a stochastic light beam propagating in the turbulent atmosphere S Avramov-Zamurovic, R Malek-Madani, C Nelson, O Korotkova , Proc. of SPIE Vol 8238, 82380J-1 2012
13. Probability density function of the intensity of a laser beam propagating in the maritime environment O Korotkova, S Avramov-Zamurovic, R Malek-Madani, C Nelson Optics express 19 (21), 20322-20331 2011
14. PDF computations for power-in-the-bucket measurements of an IR laser beam propagating in the maritime environment C Nelson, S Avramov-Zamurovic, R Malek-Madani, O Korotkova, ... Proc. of SPIE Vol 8038, 80380G-1 2011
15. Probability density function of fluctuating intensity of a laser beam propagating in marine atmospheric turbulence S Avramov-Zamurovic, O Korotkova, R Malek-Madani Proc. of SPIE Vol 7924, 792409-1 2011
16. Probability density function computations for power-in-bucket and power-in-fiber measurements of an infrared laser beam propagating in the maritime environment C Nelson, S Avramov-Zamurovic, O Korotkova, R Malek-Madani, R Sova, ... Proc. SPIE 8038, 80380G 2011